CLAIM

[1] An optical communications system using optical codes, characterized by:

an optical transmitter which:

transmits, for each piece of data of a binary data sequence, an optical code signal whose optical intensity-frequency characteristic is at least one of a function Ci(f) and a complementary function (1 – Ci(f)) of the i-th code corresponding to the value of said each piece of data of the binary data sequence, at least over an optical frequency width FSR;

said function Ci(f) is a periodic function with an optical frequency f as a variable, expressed as Ci(f) = Ci(f + FSRi);

the optical frequency width FSR is an optical frequency width which is a common multiple of a repetition period FSRi of a function forming each code in an optical frequency range from a predetermined optical frequency Fst to a predetermined optical frequency Fla;

the complementary function of the function Ci(f) is a function obtained by subtracting the function Ci(f) from 1;

the function Ci(f) and the complementary function (1 – Ci(f)) bear the following relation:

$$\int Ci(f) \cdot Ci(f)\, df > \int Ci(f) \cdot (1 - Ci(f))\, df$$

where $\int df$ is a definite integral with respect to f for an arbitrary interval FSR in the optical frequency range from Fst to Fla; and

the function Ci(f), a function Cj(f) of an arbitrary j-th code other than the i-th code and the complementary function (1 – Cj(f)) of the function Cj(f) bear the following relation:

$$\int Ci(f) \cdot Cj(f) df = \int Ci(f) \cdot (1 - Cj(f)) df;$$ and

an optical receiver which includes:

generates from said received optical signal corresponding to the difference between a first intensity signal corresponding to the optical intensity of an optical signal whose optical intensity-frequency characteristic is $Ci(f)$ based on the function $Ci(f)$ and a second intensity signal corresponding to the optical intensity of an optical signal whose optical intensity-frequency characteristic is $(1 - Ci(f))$ based on the complementary function $(1 - Ci(f))$; and regenerates said data sequence from said first difference signal.

[2] The optical communications system of claim 1, characterized in that:

said repetition period FSRi is an optical frequency width obtained by dividing said optical frequency width FSR by an integer Ni corresponding to said function $Ci(f)$; and

let Δf represent the remainder of the division of an arbitrary optical frequency width equal to or narrower than said optical frequency width FSR by the repetition period FSRi of said function $Ci(f)$, let phase $2\pi(\Delta f/FSRi)$ represent a phase difference from said function $Ci(f)$, and let $Ci'(f)= Ci(f + \Delta f)$ represent a function equal to a function $Ci(f + \Delta f)$ of the i-th code with an optical frequency $(f + \Delta f)$ different by said remainder Δf;

said functions $Ci'(f)$, $Cj(f)$ and $(1 - Cj(f))$ bear the following relation:

$\int Ci'(f) \cdot Cj(f)df = \int Ci'(f) \cdot (1 - Cj(f))df$;

said optical transmitter is a device which transmits, for each piece of data of a binary data sequence, an optical signal whose optical intensity-frequency characteristic is the function $Ci'(f)$ of each value of said remainder Δf corresponding to the value of each piece of a binary data sequence, at least in the optical frequency width FSR; and

the optical receiver is a device which regenerates the data sequence

from first difference signal corresponding to said value Δf which corresponds to the difference between: the first intensity signal generated from the received optical signal and corresponding to the optical intensity of the optical signal whose optical intensity-frequency characteristic is Ci'(f) based on each function Ci'(f) which corresponds to each value Δf transmittable by the optical transmitter; and the second intensity signal generated from the received optical signal and corresponding to the optical intensity of the optical signal whose optical intensity-frequency characteristic is (1 – Ci'(f)) based on a complementary function (1 – Ci'(f)) said function Ci'(f) which corresponds to said each value Δf.

[3] The optical communications system of claim 1, characterized in that:

said repetition period FSRi is an optical frequency width obtained by dividing said optical frequency width FSR by an integer Ni corresponding to said function Ci(f); and

let Δf represent the remainder of the division of an arbitrary optical frequency width equal to or narrower than said optical frequency width FSR by said period FSRi, let phase $2\pi(\Delta f/FSRi)$ represent a phase difference from the function Ci(f), let $\Delta f = \pi/2$ represent the phase difference, and let $Ci'(f) = Ci(f + \Delta f)$ represent a function equal to said function $Ci(f + \Delta f)$ of said i-th code at an optical frequency $(f + \Delta f)$ different by said remainder Δf;

the function Ci'(f), the function Cj(f) and the complementary function (1 – Cj(f)) bear the following relation:

$$\int Ci'(f) \cdot Cj(f)df = \int Ci'(f) \cdot (1 - Cj'(f))df;$$

said optical transmitter is a device which: separates the binary data sequence into a first separate data sequence and a second separate data sequence; outputs, as the optical code signal, an optical signal obtained by

combining: an optical signal whose optical intensity-frequency characteristic is either said function Ci(f) or (1 – Ci(f)) set by the said separate data sequence; and an optical signal corresponding to one period FSRi or FSRj of at least one of the functions Ci'(f) and Ci(f) an optical signal whose optical intensity-frequency characteristic is either at least one of the functions Ci'(f) and (1 – Ci'(f)), or at least one of the functions Cj(f) and (1 – Cj(f)) which correspond to the value of each piece of data of said second separate data sequence; and

the optical receiver is a device which: detects from the received optical signal a second difference signal corresponding to the difference between a third intensity signal corresponding to the optical intensity of the optical signal whose optical intensity-frequency characteristic is Ci'(f) or (1 – Ci'(f)) based on the function Ci'(f) or its complementary function (1 – Ci'(f)) and a fourth intensity signal corresponding to the optical intensity of the optical signal whose optical intensity-frequency characteristic is Cj(f) or (1 – Cj(f)) based on the function Cj(f) or its complementary function (1 – Cj(f)); and regenerates said first separate data sequence and said second separate data sequence from said second difference signal and said first difference signal.

[4] The optical communications system of claim 3, characterized in that:

the optical transmitter separates the input binary data sequence into first and second separate data sequences and third and fourth separate data sequences, and transmits, as an optical code signal, a combined version of said first optical signal, which has its optical intensity-frequency characteristic set to be the function Ci(f) or (1 – Ci(f)) according to the value of each piece of data of said first separate data sequence, and said second optical signal, which has its optical intensity-frequency characteristic set to be either the

function Ci'(f) or (1 – Ci'(f)), or either the function Cj(f) or (1 – Cj(f)) according to the value of each piece of data of said second separate data sequence, the both optical signals being controlled to have optical intensities corresponding to the value of each piece of data of said third separate sequence and the value of each piece of data of said fourth separate data sequence, respectively; and

said optical receiver is a device which converts said first difference signal and said second difference signal into digital values, respectively, and regenerates said, second, third and e fourth separate data sequences from these digital values, respectively.

[5] The optical communications system of claim 1, characterized in that:

said optical transmitter is a device which: receives an optical code signal whose optical frequency width is at least FSR and whose optical intensity-frequency characteristic is Cj(f) or (1 – Cj(f)); and multiplies said received optical code signal by at least one of said optical frequency characteristics Ci(f), (1 – Ci(f)), and zero in accordance with the value of each piece of data of said binary data sequence, and outputs the multiplied received optical code signal.

[6] The optical communications system of any one of claims 1 to 5, characterized in that:

said period FSRi is an optical frequency width obtained by dividing the optical frequency width FSR by an integer Ni corresponding to the function Ci(f); let Δf represent the remainder of the division of an arbitrary frequency width equal to or narrower than FSR by the repetition period FSRi of the function Ci(f); the functions Ci(f) and Cj(f) have periods FSRi and FSRj different from each other or periods FSRi and FSRj equal to each other;

let Δf represent the remainder of the division of an arbitrary frequency width equal to or narrower than FSR by the repetition period FSRi of the function Ci(f); and the function Cj(f) is Ci'(f) whose phase difference $2\pi(\Delta f/FSRi)$ from the function Ci(f) is $\pi/4$; the function Ci(f) containing a sine or cosine function.

[7] The optical communications system of any one of claims 1 to 5, characterized in that:

said optical frequency width FSR is divided into chips by a value $L = 2S \cdot Ni$ obtained by multiplying arbitrary integers S and Ni both corresponding to said function Ci(f) by an integer 2; and said function Ci(f) is a function that repeats Ni times making consecutive S chips have an optical intensity 1 and the succeeding S chips have an optical intensity 0, or sequentially shifts the optical frequency positions of said consecutive S chips of the optical intensity 1 by a predetermined value.

[8] The optical communications system of any one of claims 1 to 5, characterized in that:

said optical communications system is a two-way communication system;

an optical transmitter of at least one side of said system is a device which makes an optical signal have an optical intensity-frequency characteristic by an encoding optical filter whose optical filtering frequency characteristics are said optical filtering frequency of the function Ci(f) and its complementary function (1 – Ci(f)); and an optical receiver is a device which separates optical code signals whose optical intensity-frequency characteristics are Ci'(f) and (1 – Ci'(f)), or Cj(f) and (1 – Cj(f)) from a received optical signal by two decoding optical filters whose optical filtering characteristics are Ci'(f) and (1 – Ci'(f)), or Cj(f) and (1 – Cj(f)), where Ci'(f)

is a function displaced a quarter period apart from Ci(f);

said at least one encoding optical filter and said two decoding optical filter are integrated on a monolithic planar lightwave circuit substrate; and

said optical communications system is provided with:

intensity detecting means for detecting the optical intensity of a transmitted optical signal from said at least one encoding optical filter or said decoding optical filter; and

controlling means for controlling the temperature of said monolithic planar lightwave circuit substrate to maximize the optical intensity to be detected.

[9] The optical communications system of any one of claims 1 to 5, characterized in that:

said optical receiver is a device which:

divides said received optical signal for each optical chip forming the code of the optical code signal;

detects, as a chip intensity signal, the optical intensity of each divided optical chip; and

delays such chip intensity signals of said received optical signal corresponding to optical chips different in the time of arrival from transmission lines so that said optical chips arrive at the same time; and obtains the first difference signal by subtracting the summation those of said delayed chip intensity signals whose function (1 – Ci(f)) corresponds to 1 from the summation of those of chips in said delayed chip intensity signals whose function Ci(f) corresponds to 1.

[10] An optical transmitter, which:

receives a binary data sequence and an optical signal; and

generates by and transmits from said encoder an optical code signal

whose optical intensity-frequency characteristic is at least one of said functions Ci(f) and (1 – Ci(f)) of said i-th code corresponding to the value of each piece of data of said i-th binary data sequence at least in the optical frequency width FSR;

wherein:

said function Ci(f) is a periodic function with an optical frequency f as a variable, expressed as Ci(f) = Ci(f + FSRi);

an optical frequency width is the optical frequency width FSR which is a common multiple of a repetition period FSRi of a function forming each code in said optical frequency range from the predetermined optical frequency Fst to the predetermined optical frequency Fla;

the complementary function (1 –Ci(f) of the function Ci(f) is a function obtained by subtracting said function Ci(f) from 1;

said functions Ci(f) and (1 – Ci(f)) bear the following relation:

$$\int Ci(f) \cdot Ci(f)df > \int Ci(f) \cdot (1 - Ci(f))df$$

where $\int df$ is a definite integral with respect to f for an arbitrary interval corresponding to said optical frequency width FSR contained in the optical frequency range from the optical frequency Fst to the optical frequency Fla;

said function Ci(f), a function Cj(f) of an arbitrary j-th code other than the i-th code and a complementary function (1 – Cj(f)) of said function Cj(f) bear the following relation:

$$\int Ci(f) \cdot Cj(f)df = \int Ci(f) \cdot (1 - Cj(f))df.$$

[11] The optical transmitter of claim 10, characterized by the provision of:

N encoders for generating and outputting optical code signals whose optical intensity-frequency characteristics are different functions, said N

being an integer equal to or greater than 2; and

a combiner for combining and transmitting N sets of optical code signals.

[12] The optical transmitter of claim 11, characterized in that:

letting a represent an integer value from 1 to a value N/q by dividing the code number N by an integer q, and letting r represent the remainder of division of 2, said function Ci(f) is as follows:

$(1 + \cos(2 \cdot \pi \cdot a \cdot f/FSR + r \cdot \pi/2))/2$.

[13] The optical transmitter of claim 11, characterized in that:

said optical frequency width FSR is divided by an arbitrary integer S into chips; and

said functions Ci(f) and Cj(f) are composed of "1" and "-1" chips.

[14] The optical transmitter of claim 11, characterized in that:

each encoder is provided with: a first modulation part for generating a first optical code signal whose optical intensity-frequency characteristic is a code function assigned to said encoder; a second modulation part for generating a second optical code signal whose optical intensity-frequency characteristic is the complementary function of the function of said first modulation part; and a switch which outputs therethrough at least one of the first and second optical code signals by use of one of two values for each piece of data of input binary data and outputs at least the other of said first and second optical code signals by use of the other of said two values for each piece of data of said input binary data.

[15] The optical transmitter of claim 10, characterized in that:

said repetition period FSRi is an optical frequency obtained by dividing said optical frequency width FSR by an integer Ni corresponding to said function Ci(f); and

let Δf represent the remainder of the division of an arbitrary optical frequency equal to or narrower than said optical frequency width FSR by the period FSRi of said function Ci(f), let phase $2\pi(\Delta f/FSRi)$ represent a phase difference from said function Cj(f), and let $Ci'(f)(= Ci(f + \Delta f))$ represent a function equal to the function $Ci(f + \Delta f)$ of the i-th code at the optical frequency $(f + \Delta f)$ different by the remainder Δf from the function Ci(f);

the functions Ci'(f), Cj(f) and $(1 - Cj(f))$ bear the following relation:

$\int Ci'(f) \cdot Cj(f)df = \int Ci'(f) \cdot (1 - Cj(f))df$;

said optical transmitter is a device which transmits, for each piece of data of the binary data sequence, said function Ci'(f) of the value of said remainder Δf corresponding to the value of each piece of data, as said optical code signal at least in said optical frequency width FSR; and

said optical transmitter includes:

a sequence converting part for separating the input binary data sequence into a plurality of separate data sequences;

a code modulation part which generates, for each piece of data of each separate data sequence, an optical code signal whose optical intensity-frequency characteristic is that one of functions satisfying the conditions for the above-said relation which differs only in the phase Δf in accordance with the value of each piece of data; and

a combiner for combining the optical code signals from said code modulation parts and for outputting them as said output optical code signal.

[16] The optical transmitter of claim 10, characterized in that:

FSRi is an optical frequency width obtained by dividing FSR by an integer Ni corresponding to Ci(f); let Δf represent the remainder of the division of an arbitrary optical frequency equal to or narrower than FSR by FSRi, let phase $2\pi(\Delta f/FSRi)$ represent a phase difference from the function

$Ci(f)$, and let $Ci'(f)(= Ci(f + \Delta f))$ represent a function equal to the function $Ci(+ \Delta f)$ of the i-th code at the optical frequency $(f + \Delta f)$ different by the remainder Δf from said function $Ci(f)$; and

said functions $Ci'(f)$, $Cj(f)$ and $(1 - Cj(f))$ bear the following relation:

$\int Ci'(f) \cdot Cj(f)df = \int Ci'(f) \cdot (1 - Cj(f))df$;

$\Delta f = \pi/2$; and

said optical transmitter is provided with:

a sequence converting part for separating said input binary data sequence into a first separate data sequence and a second separate data sequence;

a first modulation part for generating, based on the first separate data sequence, a first optical signal whose optical intensity-frequency characteristic is set to be said function $Ci(f)$ or $(1 - Ci(f))$, depending on the value of each piece of data of said first separate data sequence;

a second modulation part for generating a second optical signal whose optical intensity-frequency characteristic is at least one of said functions $Ci'(f)$ and $(1 - Ci'(f))$, or at least one of said functions $Cj(f)$ and $(1 - Cj(f))$ and corresponding to at least one period FSRi or FSRj of the function $Ci'(f)$ or $Cj(f)$ of the second optical signal, depending on the value of each piece of data of said second separate data sequence; and

a combiner for combining said first and the second optical signals and for outputting them as optical code signal.

[17] The optical transmitter of claim 16, characterized in that:

said sequence converting part is a converting part which converts the input binary data sequence into first, second, third and fourth separate data sequences;

said optical transmitter is provided with third and fourth modulation

parts for modulating said first and second optical signals into signals of optical intensities corresponding to the values of respective pieces of data of said third and fourth separate data sequences, respectively; and

said combiner combines the output light from the third modulating part and the fourth modulating part.

[18] The optical transmitter of any one of claims 15 to 17, characterized in that:

said period FSRi is an optical frequency width obtained by dividing said optical frequency width FSR by an integer Ni corresponding to said function Ci(f); let Δf represent the remainder of the division of an arbitrary frequency width equal to or narrower than said arbitrary frequency width FSR by the repetition period FSRi of said function Ci(f); the periods of said functions Ci(f) and Cj(f) are the periods FSRi and FSRj different from each other or periods FSRi and FSRj equal to each other; let Δf represent the remainder of the division of an arbitrary frequency width equal to or narrower than said optical frequency width FSR by the repetition period FSRi of the function Ci(f); said function Cj(f) is Ci'(f) which has a phase $2\pi(\Delta f/FSRi)$ from said function Ci(f) is $\pi/4$ and is a function containing a sine or cosine function.

[19] The optical transmitter of any one of claims 15 to 17, characterized in that:

said optical frequency width FSR is divided into chips by a value $L = 2S \cdot Ni$ obtained by multiplying arbitrary integers S and Ni both corresponding to the code function Ci(f) by an integer 2; and said function Ci(f) is a function that repeats Ni times making consecutive S chips have an optical intensity 1 and the succeeding Si chips have an optical intensity 0, or sequentially shifts the optical frequency positions of said consecutive Si chips

of the optical intensity 1 by a predetermined value.

[20] The optical transmitter of any one of claims 15 to 17, characterized in that there are provided:

a light source for outputting an optical frequency signal with the predetermined optical frequency width (FSR) contained in the range from the predetermined optical frequency Fst to the predetermined optical frequency Fla;

an optical splitter for splitting an output optical signal from light source into multiple optical signals;

a plurality of optical filters whose optical filtering-frequency characteristics are different code functions, for receiving said split optical signals;

an optical combiner for combining said optical signals transmitted through said optical filters and transmitting said combined output as an optical code signal.; and

code modulating means which is inserted between said multiple optical filters and said optical splitter or optical combiner and controlled by the multiple separate data sequences.

[21] The optical transmitter of any one of claims 15 to 17, comprising:

at least NL light sources for outputting optical signals of optical frequencies corresponding to NL chips each having a chip width that is a unit optical frequency width obtained by dividing the optical frequency width FSR by a natural number N and an integer equal to or greater than 3;

drive signal generators for generating drive signals for driving the NL light sources;

an optical multiplexer for multiplexing optical outputs from the NL light sources and outputting the multiplexed optical outputs as an optical code

signal; and

code modulating means inserted between the NL light sources and the drive signal generators or the optical multiplexer and controlled by the multiple separate data sequences.

[22] An optical receiver characterized by:

filter means which permits the passage therethrough of an optical signal having an optical intensity-frequency characteristic based on a function;

intensity detecting means for detecting the optical intensity of said optical signal; and

means for adding together or subtracting the intensity signals from each other; and

which is supplied with the received optical signal and regenerates data corresponding to the difference between: a first intensity signal corresponding to the optical intensity of an optical signal having an optical intensity-frequency characteristic Ci(f) based on a frequency characteristic function Ci(f); and a second intensity signal corresponding to the optical intensity of an optical signal having an optical intensity-frequency characteristic (1 – Ci(f)) based on the complementary frequency function (1 – Ci(f));

wherein:

said function Ci(f) is a periodic function expressed as Ci(f) = Ci(f + FSRi), the value of the function Ci(f) being in the range of 0 to 1;

an optical frequency width FSR is an optical frequency width which is a common multiple of a repetition period FSRi of a function forming each code in the optical frequency range from the predetermined optical frequency Fst to the predetermined optical frequency Fla;

said complementary function of the function Ci(f) is a function obtained by subtracting said function Ci(f) from 1;

said functions Ci(f) and (1 – Ci(f)) bear the following relation:

$\int Ci(f) \cdot Ci(f)df > \int Ci(f) \cdot (1 - Ci(f))df$

where $\int df$ is a definite integral with respect to f for an arbitrary interval FSR corresponding to said optical frequency width FSR contained in said optical frequency range from the optical frequency Fst to the optical frequency Fla; and

said function Ci(f), a function Cj(f) of an arbitrary j-th code Cj(f) other than said i-th code and the complementary function (1 – Cj(f)) of said function Cj(f) bear the following relation:

$\int Ci(f) \cdot Cj(f)df = \int Ci(f) \cdot (1 - Cj(f))df.$

[23] The optical receiver of claim 22, wherein:

said received optical signal is multiple optical code signals encoded to have optical intensity-frequency characteristics that satisfy orthogonality relations; and

said optical transmitter further comprising multiple decoders, each provided with:

a splitter which is supplied with and splits one of said received optical signals into multiple optical signals;

a first filter which is supplied with one of said received optical signals split by said splitter and whose filtering optical characteristic is Ci(f);

a first intensity detector which is supplied with the output from said first filter and detects its optical intensity as a first intensity signal;

a second filter which is supplied with one of said optical signal and whose filtering optical characteristic is (1 – Ci(f));

a second intensity detector which is supplied with the output from said

second filter and detects its optical intensity as a second intensity signal; and

an intensity difference detector which is supplied with said first and second intensity signals and regenerates binary data based on the intensity difference obtained by subtracting the one from the other intensity signal, respectively;

wherein said functions Ci(f) and (1 – Ci(f)) differ between said multiple decoders.

[24] The optical receiver of claim 23, characterized in that:

letting a represent an integer value in the range from 1 to an integer value N/2 obtained by dividing the code number N by an integer q and letting r represent the remainder of q, the function Ci(f) is as follows:

$(1 + \cos(2 \cdot \pi \cdot a \cdot f/FSR + r \cdot \pi/2))/2$.

[25] The optical receiver of claim 23, wherein:

said optical frequency width FSR is divided by an arbitrary integer S into chips; and

said function Ci(f) and the function Cj(f) are composed of "1" and "-1" chips;

said optical receiver further comprising:

a filter which is supplied with said received optical signal and divides and outputs said received input signal for each chip;

multiple chip intensity detectors each of which is supplied with the filter output for each chip and detects the chip intensity signal corresponding to the optical intensity of said optical signal for each chip; and

an intensity difference detector which is supplied with the chip intensity signals from said multiple chip intensity detectors, makes positive the chip intensity signals each corresponding to each chip "1" of the function Ci(f) and negative the chip intensity signals each corresponding to a chip "1"

of the function $(1 - Ci(f))$, and outputs binary data based on the summation of all the input chip intensity signals with that signal corresponding to each "1" chip of said function $Ci(f)$ held positive and that signal corresponding to each "1" of said function $(1 - Ci(f))$held negative.

[26] The optical signal receiver of claim 22, wherein:

said FSRi is an optical frequency width obtained by dividing said optical frequency width FSR by an integer Ni corresponding to said function $Ci(f)$; and

let Δf represent the remainder of the division of an arbitrary optical frequency equal to or narrower than FSR by FSRi, let phase $2\pi(\Delta f/FSRi)$ represent a phase difference from the function $Ci(f)$, and let $Ci'(f)(= Ci(f + \Delta f))$ represent a function equal to the function $Ci(f + \Delta f)$ of the i-th code at the optical frequency $(f + \Delta f)$ different by the remainder Δf from the function $Ci(f)$;

said functions $Ci'(f)$, $Cj(f)$ and $(1 - Cj(f))$ bear the following relation:

$\int Ci'(f) \cdot Cj(f)df = \int Ci'(f) \cdot (1 - Cj(f))df$;

said optical signal receiver further comprising:

a first filter which is supplied with said received optical signal and whose optical filtering frequency characteristic is said function $Ci'(f)$ corresponding to value of said reminder Δf transmittable from an optical transmitter of the communicating partner;

a second filter which is supplied with said received optical signal and whose optical filtering frequency characteristic is said function $(1 - Ci'(f))$ corresponding to the function $Ci'(f)$ which corresponds to the value Δf transmittable from the source optical transmitter;

a first intensity detectors which are supplied with the output from the first filters and detect a first intensity signals corresponding to the optical

intensities of the output from said first filters;

a second intensity detectors which are supplied with the output from said second filters and detect a second intensity signal corresponding to the optical intensities of the output from said second filters; and

means which are supplied with said first and second intensity signals, detect the difference therebetween, and regenerates and outputs the binary data sequence.

[27] The optical receiver of claim 22, wherein:

said FSRi is an optical frequency width obtained by dividing said optical frequency width FSR by an integer Ni corresponding to Ci(f); and

let Δf represent the remainder of the division of an arbitrary optical frequency equal to or narrower than FSR by FSRi, let phase $2\pi(\Delta f/PFRi)$ represent a phase difference from said function Ci(f), let Ci'(f)(= Ci(f + Δf)) represent a function equal to the function Ci(f + Δf) of the i-th code at the optical frequency (f + Δf) different by the remainder Δf from the function Ci(f), and let said phase difference be set at $\pi/2$;

said functions Ci'(f), Cj(f) and (1 − Cj(f)) bear the following relation:

$\int Ci'(f) \cdot Cj(f)df = \int Ci'(f) \cdot (1 - Cj(f))df$;

said optical receiver further comprising:

a first filter which is supplied with said received optical signal and whose optical filtering frequency characteristic is said function Ci(f);

a second filter which is supplied with said received optical signal and whose optical filtering frequency characteristic is said function (1 − Ci(f));

a first intensity detector which is supplied with the output from said first filter and detects a first intensity signal corresponding to the optical intensity of the output from said first filter;

a second intensity detector which is supplied with the output from said

second filter and detects a second intensity signal corresponding to the optical intensity of the output from said second filter;

a third filter which is supplied with the received optical signal and whose optical filtering frequency characteristic is said function Ci'(f) or Cj(f);

a fourth filter which is supplied with said received optical signal and whose optical filtering frequency characteristic is said function (1 – Ci'(f)) or (1 – Cj(f));

a third intensity detector which is supplied with the output from said third filter and detects a third intensity signal corresponding to the optical intensity of the output from said third filter;

a fourth intensity detector which is supplied with the output from said fourth filter and detects a fourth intensity signal corresponding to the optical intensity of the output from said fourth filter;

a first subtractor which is supplied with said first intensity signal and the second intensity signal and outputs the difference therebetween as a first difference signal;

a second subtractor which is supplied with said second and fourth intensity signals and outputs the difference therebetween as a second difference signal; and

data generating means which is supplied with said first and second difference signals and outputs said binary data sequence.

[28] The optical receiver of claim 27, characterized in that:

said data generating means is means which renders said first difference signal into first binary data and said second difference signal into second binary data, and arranges said first binary data and said second binary data in a sequential order to form said binary data sequence.

[29] The optical receiver of claim 27, characterized in that:

said data generating means is provided with:

a first A/D converter for converting said first difference signal to a first digital value;

a second A/D converter for converting said second difference signal to a second digital value; and

binary sequencing means which is supplied with said first and second digital signals, and outputs that one of predetermined combinations of four or more pieces of data 0 or 1 for a combination of the values of said input digital signals.

[30] The optical receiver of any one of claims 26 to 29, characterized in that:

the period FSRi is an optical frequency width obtained by dividing the optical frequency width FSR by an integer Ni corresponding to the function Ci(f), and let Δ represent the remainder of the division of an arbitrary frequency width equal to or narrower than FSR by the repetition period FSRi of the function Ci(f);

said functions Ci(f) and Cj(f) have either the periods FSRi and FSRj different from each other or periods FSRi and FSRj equal to each other, in which case let Δf represent the remainder of the division of an optical frequency width equal to or narrower than that said optical frequency width FSR by the repetition period FSRi of said function Ci(f), and said function Cj(f) is Ci'(f) whose phase $2\pi(\Delta f/FSRi)$ of the function Ci(f) is $\pi/4$.

[31] The optical receiver of any one of claims 26 to 29, wherein:

said optical frequency width FSR is divided into chips by a value $L = 2Si \cdot Ni$ obtained by multiplying arbitrary integers Si and Ni both corresponding to said function Ci(f) by an integer 2; and

said functions Ci(f) and Cj(f) are composed of "1" and "-1" chips,

respectively;

said optical receiver further comprising:

a filter which is supplied with said received optical signal and divides and outputs said received input signal for each chip;

multiple chip intensity detectors each of which is supplied with the filter output for each chip and detects the chip intensity signal corresponding to the optical intensity of said optical signal for each chip; and

an intensity difference detector which is supplied with the chip intensity signals from said multiple chip intensity detectors, makes positive the chip intensity signals each corresponding to a chip "1" of the function Ci(f) and negative the chip intensity signals each corresponding to each chip "1" of the function (1 – Ci(f)), and outputs binary data based on the summation of all the inputs.

[32] Reflective optical communication equipment which is supplied with a received optical signal and a binary data sequence, modulates the received the optical signal to an optical signal whose optical intensity-frequency characteristic is a function with an optical frequency f as a variable, and transmits the modulated optical signal, and which characterized by:

an encoder which is supplied with said received optical signal of at least an optical frequency width FSR and outputs an optical signal by an optical filtering frequency characteristic of a first function Ci(f);

a complementary encoder which is supplied with said received optical signal and outputs a complementary optical signal filtered by a filtering optical frequency characteristic of a complementary function (1 – Ci(f)); and

selective combining means which selectively combines, according to the value of each piece of data, the optical signal and the complementary

optical signal and transmits them as an optical code signal;

wherein:

said function Ci(f) is a periodic function expressed as Ci(f) = Ci(f + FSRi), the value of said function Ci(f) being in the range of 0 to 1;

said optical frequency width FSR is an optical frequency width which is a common multiple of a repetition period FSRi of a function forming each code in said optical frequency range from the predetermined optical frequency Fst to the predetermined optical frequency Fla;

the complementary function of said function Ci(f) is a function obtained by subtracting said function Ci(f) from 1;

said function Ci(f) and (1 – Ci(f)) bear the following relation:

$$\int Ci(f) \cdot Ci(f)df > \int Ci(f) \cdot (1 - Ci(f))df$$

where $\int df$ is a definite integral with respect to f for an arbitrary interval corresponding to said optical frequency width FSR in the optical frequency range from the optical frequency Fst to the optical frequency Fla; and

said function Ci(f), a function Cj(f) of an arbitrary j-th code other than said i-th code and the complementary function (1 – Cj(f)) of said function Cj(f) bear the following relation:

$$\int Ci(f) \cdot Cj(f)df = \int Ci(f) \cdot (1 - Cj(f))df.$$

[33] The reflective optical communication equipment of claim 32, which is characterized by:

a decoder which is supplied with said received optical signal and whose optical filtering frequency characteristic is said function Cj(f));

a complementary decoder which is supplied with said received optical signal and whose optical filtering frequency characteristic is said function (1 – Cj(f));

a first optical detector which is supplied with the output light from said decoder and outputs an intensity signal corresponding to the optical intensity of the output light from said decoder;

a complementary optical detector which is supplied with the output light from said complementary decoder and outputs a complementary intensity signal corresponding to the optical intensity of the output light from said complementary decoder; and

a comparator which is supplied with said intensity signal and said complementary intensity signal and outputs one of two pieces of data in accordance with the level difference between said intensity signals when the difference exceeds a predetermined value.

[34] The reflective optical communication equipment of claim 33, characterized in that the selective multiplexing means is provided with: a total reflector and a complementary total reflector for totally reflecting back to the encoder and the complementary encoder; and selectors and complementary selectors disposed between said encoder and the complementary encoder and between said total reflector and said complementary total reflector, respectively, for selecting either one of said optical signal and an optical signal complementary thereto in accordance with the value of input data.

[35] The reflective optical transmission equipment of claim 33, which is characterized by:

optical amplifiers for use as said optical detector and said complementary optical detector for optically amplifying the input optical signals and outputting the amplified optical signals and intensity signals corresponding to the optical intensities of said input optical signals; and

an optical combiner for combining the amplified optical signals from said optical detector and said complementary optical detector and inputting

the combiner optical signal as said received optical signal to said encoder and said complementary encoder.

[36] The reflective optical communication equipment of claim 33, which is characterized by:

a switch for selecting said optical signal or complementary optical signal in accordance with the value of input data;

an optical combiner/splitter which is supplied with the output from said switch, splits said output into two, and inputs one of them to said decoder and said complementary decoder; and

a total reflector which is supplied with the other split light from said optical combiner/splitter and totally reflects the input light.

[37] The reflective optical communication equipment of claim 33, characterized by:

a switch for selecting said optical signal or said complementary optical signal in accordance with the value of input data; and

a partial reflector which is supplied with the output light from said switch, reflects a portion of the output light and inputs the remaining portion of said output light to said decoder and said complementary decoder.

[38] The reflective optical communication equipment of any one of claims 33 to 37, characterized in that:

said period FSRi is an optical frequency width obtained by dividing said optical frequency width FSR by an integer Ni corresponding to said function Ci(f); let Δf represent the remainder of the division of an optical frequency width equal to or narrower than said optical frequency width FSR by the repetition period PFRi of the function Ci(f); said functions Ci(f) and Cj(f) have either the periods FSRi and FSRj different from each other or periods FSRi and FSRj equal to each other; let Δf represent the remainder of

the division of an arbitrary frequency width equal to or narrower than FSR by the repetition period FSRi of the function Ci(f); said function Cj(f) is Ci'(f) whose phase $2\pi(\Delta f/FSRi)$ from said function Ci(f) is $\pi/4$; and said function Ci(f) is a trigonometric function;

said encoder and said complementary encoder are integrated as an output encoder; and said decoder and said complementary decoder are integrated as an input decoder.

[39] The reflective optical communication equipment of any one of claims 33 to 37, characterized in that:

said optical frequency width FSR is divided into chips by a value $L = 2S \cdot Ni$ obtained by multiplying arbitrary integers S and Ni both corresponding to said function Ci(f) by an integer 2; and said function Ci(f) is a function that repeats Ni times making consecutive S chips have an optical intensity 1 and the succeeding S chips have an optical intensity 0, or sequentially shifts the optical frequency positions of said consecutive S chips of the optical intensity 1 by a predetermined value;

said encoder and said complementary encoder are integrated as an output encoder; and said decoder and said complementary decoder are integrated as an input decoder.